and all of the attendant biological effects mentioned earlier. For comparison, the IEEE/AN SI safe exposure limit is l.6 mW/g and even that level is facing strong opposition as being too high.

4

Computer analysis and measurements, which specifically considered the effects from portable antennas in close proximity to a human head, also show that about 50 percent of the radiated energy is absorbed in the head of the operator.[11] Graphic illustrations of the energy absorption profile clearly show very high absorption levels at the region of the head closest to the antenna.

The electromagnetic field exposure of a portable cellular telephone user depends on the type of antenna and its position.[12] There is a wide variety of antennas available, and each provides its own unique pattern of radiation into the head and brain. Some antennas are so efficient at directing radiation into the head and brain that they are used for diathermy and hyperthermia therapies. Depending on the type of antenna used, as much as 90 percent of the radiated energy can be absorbed within the head and brain of the user. These researchers also have reconfirmed that operation of commercially available portable cellular telephones provides for 50 percent or more of the radiated

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[11] *H J. Toftgard, et al., "Effects on Portable Antennas of the Presence of a Person," IEEE Transactions on Antennas and Propagation 41, no. 6 (June 1993): 739-46.*

[12] *V. Hombach, and H. Thielen, Investigations on Antennas for Hand-Held Telephones with Minimum EM -Field Exposure of the User, 16th Annual Bioelectromagnetics Society Meeting, June 12-17, 1994, abstract book, p. 12.*

energy to be absorbed in the head of the user. They obtained the results with a simple homogeneous laboratory model. The simple, single material models understate the actual absorption that would occur in a human. Even so, their SAR levels indicate exposure at more than 5 mW/g for some antennas. Had they used a more complex, multilayered model the results would have indicated significantly higher radiation absorption by the user.

That energy absorption and conversion can, and does, lead to a dangerous temperature increase.[13,14] It's a thermal issue in addition to a nonthermal issue. Some researchers now believe that nonthermal effects may be dramatically multiplied in the presence of significant tissue heating.

Most of the temperature rise associated with the energy absorption takes place in the first sixty to ninety seconds of exposure. This finding is inconsistent with the cellular telephone industry's recommendation which suggests that if users are concerned about the effects of radiation they should make short calls to reduce the hazards of operation. From what the research data indicates, the definition of a short call would need to be much less than one minute—probably less than thirty seconds. In other words, based on these research findings and the industry's warnings portable cellular telephones should not be used.

Absorption of RF energy, with the use of selective shielding, revealed that the most sensitive area for absorption is over the temporal lobe of the brain and at

[13] *H. P. Schwan and G. M. Piersol, "The Absorption of Electromagnetic Energy in Body Tissues," International Review of Physical Medicine and Rehabilitation, June 1955, pp. 424-48.*

[14] *S. F. Cleary, "Uncertainties in the Evaluation of the Biological Effects of Microwave and Radiofrequency Radiation," Health Physics 25 (October 1973): pp. 387-404.*

frequencies from 300 to 1200 MHz.[15] This brings our attention to the issue of localized radiation absorptions and the possibility of damage to small areas in the head and brain.

> **"It should be understood that a cumulative effect is the accumulation of damage resulting from repeated exposures each of which is individually capable of producing some small degree of damage. In other words, a single exposure can result in covert thermal injury, but the incurred damage repairs itself within a sufficient time period, for example hours or days, and therefore is reversible and does not advance to a noticeable permanent, or semi-permanent state. If a second exposure or several repetitive exposures take place at time intervals shorter than that needed for repair, damage can advance to a noticeable stage."[16]**

What we learn is that a repeated insult or irritation to a particular biological area, such as a small region of the brain, can lead to irreparable damage. That is, given the existence of energy absorption "hot spots," the existence of which have been verified by numerous researchers, then each damaging exposure to radiofrequency radiation provides a new opportunity that the damage will become permanent. Part of the problem is that an exposed person would never know of the penetration and damage.

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[15] *I. J. Bahl, et al., "Microstrip Loop Radiators for Medical Applications," IEEE Transactions on Microwave Theory and Techniques MIT-30, no. 7 (July 1982) 1090-93.*

[16] *S. M. Michaelson, "Human Exposure to Nonionizing Radiant Energy—Potential Hazards and Safety Standard's," Proceedings of the IEEE, April 1972, pp. 389-421.*

Perhaps even more troublesome is that tissue damage in the body is usually followed by a process of repair or restoration. So, each damaging exposure is likely to activate the growth of new cells to replace damaged or destroyed tissue. Cells that participate in the repair process are also likely to be some of the cells that were earlier damaged.

S. M. Michaelson reported that the thermal sensation of pain is evoked when thermal sensors in the skin reach approximately 46°C. From data given in that same research report we learn that no sensation of warmth would be felt in the skin, or scalp, until a dose of radiofrequency radiation was so high that internal damage to deep tissue was certain to result.

Researchers have pointed out that electromagnetic energy in the 900MHz region may be more harmful because of its greater penetrating capability compared to 2450 Mhz. [17,18] More of the energy in the 900 MHz frequency range is deposited deeply within biological tissue.

J. C. Lin concluded that 918 MHz energy constitutes a greater health hazard to the human brain than does 2450 MHz energy for a similar incident power density.

For these experiments he used a complex six-layered model of the human head that indicates peak SARs approximately 50 percent higher than simpler models and an average head absorption about five times higher than the single layered homogeneous models.

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[17] *J. C. Lin, "Interaction of Two Cross-Polarized Electromagnetic Waves with Mammalian Cranial Structures," IEEE Transactions on Biomedical Engineering BME-23, no. 5 (September 197 6): 371-75.*

[18] *E. Friedenthal, et al., "Hyperthermia in the Treatment of Local Recurrence of Breast Cancer," Microwave Journal, May 1984, pp. 275-82. .*

Radiofrequency radiation and radiofrequency energy generated by cellular telephones are comprised of both electric and magnetic fields. Some researchers prefer to work only with the magnetic fields while ignoring the accompanying electric fields. An SAR relationship that is based exclusively on magnetic fields also indicates that the ANSI safety standards cannot be met for existing portable radio and telephone products. For an antenna placed at 1.5 cm from the surface of a flat layered model and radiating 0.6 watts, the experimental data indicate an energy absorption level of about 3.0 mW/g inside a human skull and a penetration depth of about 3 cm into the simulated brain tissue.[19]

The information simply reconfirms the body of research that has preceded. That is, energy absorbed into the head and brain of a user is dangerously high and in excess of the safety standards—if only the safety standards applied.

Twenty years ago industry researchers pitched the notion that the radiofrequency energy from portable transmitting devices was not absorbed into the head.

Now they admit that the energy is absorbed deep within the head. When these researchers established their original position it was based on the premise that there was a "peculiar nature" of the fields that stopped the energy at the surface of the human head. Apparently that `special physics` for portable transmitting radios and portable cellular telephones has become outdated.

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[19] *N. Kuster and Q. Balzano, "Energy Absorption Mechanism by Biological Bodies in the Near Field of Dipole Antennas above 300 MHz," IEEE Transactions on Vehicular Technology 41, no. 1 (February 1992).·17—23.*

These industry researchers have provided even more convincing data from experiments with models simulatiung the human head as energy absorption levels of about 3.5 mW/g were reported.

Industry researchers, typically, have employed the most favorable models possible to yield the lowest level of energy absorption. Nevertheless, they arrive at absorption levels in the 3.0 mW/g range. Other researchers have shown that multilayer laboratory models provide energy absorption results that are 3 to 5 times higher than the simplified models. As such, we would expect that more accurate SARs would be in the range of 9-15 mW/g with a multilayered model.

To this point "hot spot" absorption mechanisms and nonuniform radiation emission in the near-zone have been ignored. If the numerous energy focusing and "hot spot" mechanisms are factored into the calculations the peak levels will be much higher; they would be on the order of 20-50 mW/g at very localized areas of a human head and brain. It's not difficult to envision that the human brain is a collection of billions of molecules and interconnecting links, or bonds. Even one cubic centimeter of brain tissue includes billions of molecules and interconnecting bonds. Each of these molecules or bonds may be susceptible to extremely high energy absorption under certain conditions even while other molecules, only a short distance away, might be exposed to lower energy levels. Even as large variations in absorption levels are reported for macroscopic measurements we should expect even greater variations in absorption levels when looking at the microscopic or molecular level. Large temperature changes can be expected within biological tissue as a result of absorbing high levels of radiofrequency radiation.

Experiments show that a five—minute exposure to a surface power density of 100 mW/cm^2 at 710 MHz yields an internal temperature rise of 12°C.[20] If that exposure level were scaled back to what users of portable telephones experience, 10-20 mW/cm^2, the equivalent temperature rise within the tissue would be about 1.2—2.4°C, not counting any increased absorptions due to "hot spots." That is for only a five-minute exposure.

Tissue destruction is a sharp function of temperature, and a variation of only a fraction of a degree can mean the difference between acceptable and unacceptable damage to normal tissue.[21] We are reminded that low-frequency (less than 100 MHz) and very high-frequency radiation (more than about 3,000 MHz) is not well suited for deep absorption into biological tissue, the reason being that radiofrequency radiation of intermediate frequency, such as 918 MHz, is most efficiently absorbed into tissue. For his purposes, hyperthermia treatment of patients, L. S. Taylor advises that complex systems must be designed to prevent "hot spots." Although many "hot spots" and "hot spot" generating mechanisms have been related to cellular telephone transmitting antennas there are still no designs, or redesigns, to eliminate the "hot spot" radiation absorption.

In the following chapter the topic of "hot spots" will be considered in detail.

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[20] *O. P. Gandhi, "Conditions of Strongest Electromagnetic Power Deposition in Man and Animals," IEEE Transactions on Microwave Theory and Techniques MTT-23, no. 12 (December 1975):1021-29.*
[21] *L. S. Taylor, "Implantable Radiators for Cancer Therapy by Microwave Hyperthermia," Proceedings of the IEEE 68, no. 1 (January 1980):142-149.*

6

In studies of diathermy applications it is consistently shown that electromagnetic energy at frequencies near and below 900 MHz is best suited for deep penetration into brain tissue. The depth of penetration is noticeable greater at this lower frequency range, which includes the portable cellular phone transmit frequencies.[22,23,24]

Diathermy treatment experiments conducted at 750 MHz and 915 MHz yield energy absorption and tissue-heating characteristics so similar as to be indistinguishable.[25] The researchers who performed these particular experiments found that deep tissue heating is obtained at either frequency without significant heating in the surface tissues.

It is important to note that researchers interested in characterizing the performance of diathermy applicators will naturally conduct experimental research at those frequencies authorized for diathermy use. That's why nearly all of the diathermy energy absorption work is performed at about 750 MHz, 915 MHz, or 2,450 MHz. In the preceding work the researchers confirmed that

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[22] *J. F. Lehmann, et al., "A Comparative Evaluation of Temperature Distributions Produced by Microwaves at 2,456 and 900 Megacycles in Geometrically Complex Specimens," Archives of Physical Medicine and Rehabilitation (October 1962):502-07.*

[22] *A. W. Guy, et al., "Therapeutic Applications of Electromagnetic Power," Proceedings of the IEEE 62, no. 1 (January 1974):55-75.*

[24] *J. F. Lehmann, et al., "Comparison of Relative Heating Pat-*
9 terns Produced in Tissues by Exposure to Microwave Energy at Frequencies of 2,450 and 900 Megacycles," Archives of Physical Medicine and Rehabilitation, February 1962, pp. 69-76.

[25] *J. F. Lehmann, et al., "Evaluation of a Microwave Contact Applicator," Archives of Physical Medicine and Rehabilitation, March1970, pp. 143-46.*

there is no difference in the energy absorption characteristics between 750 MHz and 915 MHz.

Of course, for diathermy treatment tissue damage is undesirable. But some researchers began to develop an idea that heating cancerous tissue to destruction could be a useful technique in the treatment of tumors. This technique is known as hyperthermia therapy. Hyperthermia has been defined as any temperature in human tissue exceeding 41°C, but not including fever or heatstroke. Research has concluded that the frequency range of greatest energy penetration and practical hyperthermia application extends from about 100 MHz to 1,000 MHz.[26]

Although 915 MHz is authorized in the United States for hyperthermia, researchers have found that 750 MHz is also a good choice due to the excellent deep energy absorption at that frequency.

> **By their nature the frequencies that provide the best therapeutic heating would also be frequencies that could be most hazardous to man in an uncontrolled situation.**[27]

High absorption in inner tissue such as the brain occurs while fat and bone absorption is many times less. That is, radiofrequency radiation passes through fat and bone to be absorbed within the brain. Researchers note that

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[26] *J. G. Short and P. F. Turner, "Physical Hyperthermia and Cancer Therapy," Proceedings of the IEEE 68, no. 1 (January 1980):133-42.*

[27] *C. C. Johnson and A. W. Guy, "Nonionizing Electromagnetic Wave Effects in Biological Materials and Systems," Proceedings of the IEEE 60, no. 6 (June, 1972):692-718.*

"local lesions of the skin and underlying tissues due to thermal arrears from microwave exposure have been observed. These microwave burns tend to be deep, like fourth-degree burns, due to the deep penetration of the energy". (see footnote 27).

They also remind us that the heating characteristics of RF energy provide deep heating of 43°C-45°C, which is in the range where tissue destruction occurs. Human brain tissue is even more susceptible—perhaps the most sensitive—to increases in temperature. Brain tissue can begin to suffer damage with a temperature increase of as little as (0.5°C).
Particularly, it is known that radiofrequency energy absorption causes heating in tissue that has three primary effects: (1) tissue destruction and death; (2) inhibition of normal cell growth through depression of enzyme activity; and (3) increase in membrane permeability. This last effect is the low-level exposure—induced effect being researched by Adey and others.

As if the energy absorption issue itself weren't enough, there is considerable evidence that radiofrequency energy exposure may inactivate enzymes or proteins that are involved in the repair process to correct DNA breaks. As long ago as 1980 it was proposed that radiofrequency energy exposure was responsible for inhibiting repairs to DNA.

7

Researchers have confirmed that localized hyperthermia is much easier to induce using radiofrequency energy deposition than with other methods. Further, they reported that. 915 MHz is suitable to heat more massive and deeper tissue. Using 915 MHz radiation researchers have found that they can focus energy absorption into highly localized regions of deep penetration up to 6 cm.[28] By focusing the energy into a "hot spot" the amount of power required from an energy source is reduced by a factor of more than 20. Conversely, this means that an energy-radiating element, such as an antenna, can provide enhanced focused energy deposition.

The destructive effect of heat on malignant as well as healthy tissues is a function of the temperature to which the tissue is raised.[29]

In similar research at other universities, techniques were developed for deep tissue absorption of 915 MHz energy by using antennas.[30,31,32]

This knowledge of the deep penetration of radiofrequency radiation has made hyperthermia very attractive. 'The frequency range 700-950 MHz continues to be the

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[28] *C. Q. Wang and O. P. Gandhi, "Numerical Simulation of Annulur Phased Arrays for Anatomically Based Models Using the FDTD Method," IEEE Transactions on Microwave Theory and Techniques MIT-37, no. 1, (January 1989):118-26.*

[29] *F. Sterzer, "Localized Hyperthermia Treatment of Cancer," RCA Review 42 (December 1981):727-51.*

[30] *A. W. Guy, et al., "915—MHz Phased-Array System for Treating Tumors in Cylindrical Structures," IEEE Transactions on Microwave Theory and Techniques MTT-34, no. 5 (May 1986):502-07.*

[31] *A. M. Tumeh and M. F. Iskander, "Permost studied. However, in the United States 915 MHz is the authorized industrial, scientific, and medical frequency. Researchers, therapists, and oncologists would prefer to use a frequency around 850 MHz since that is the region for maximum energy absorption by living tissue.*

[32] *P. F. Wahid, et al., "Multidipole Applicators for Regional and Whole-Body Hyperthermia," Proceedings of the IEEE 70, no. 3 March 1982):311-13.*

most studied. However, in the United States 915 MHz is the authorized industrial, scientific, and medical frequency. Researchers, therapists, and oncologists would prefer to use a frequency around 850 MHz since that is the region for maximum energy absorption by living tissue.

The frequency range of portable cellular telephone transmissions, 825-845 MHz, was not deliberately chosen to coincide with the most dangerous frequency range known. to man. It was selected because that is the frequency range alloted by the Federal Communications Commission. It may just be coincidence that the manufacturers also possessed a very strong engineering capability at that frequency range. They were already selling mobile radios in the 800 MHz frequency range. That eliminated any need to develop an expertise at a new frequency range. And as anyone familiar with communications and radio engineering knows, shifting to an unknown frequency range brings with it an entirely unknown package of new problems. No doubt the manufacturers have experienced such a new problem set while developing the new personal communications system (PCS), which will operate in the 1700-1900 MHz range. In any event, the 825-45 MHz frequency band was either by accident or by deliberate act the best for the manufacturers and the worst for the consumers. As we have learned, even at the time that the frequency allocation was made the research results clearly indicated the danger.

8

The birth of RF and microwave frequency diathermy and hyperthermia, both of which are controlled clinical exposures, coincides with many uncontrolled exposures. Operators of equipment were exposed to the energy in a way that was not well known or prescribed. Such uncontrolled exposures are similar to exposures that occur with operation and maintenance of radar systems and communication systems.

Lehmann, Stonebridge, and Guy have advised that

> ***Undesirable side effects of diathermy treatment would include formation of cataracts, degenerative changes of the gonads, and brain damage . . .*** [33]

Earlier research had confirmed the formation of cataracts due to radiofrequency radiation exposure. So, diathermy treatment therapists were considered susceptible to the harmful effects of radiofrequency radiation emitted from the applicators. The concern about brain damage is partly from knowledge that brain tissue readily absorbs energy in the 700-950 MHz frequency range and is also very sensitive to temperature variations. This concern is significant. By comparison radiofrequency energy exposures to diathermy therapists are lower than those experienced from operation of portable cellular telephones.

The maximum allowable stray field exposure levels for diathermy applicators are set at a radiation level of 5 mW/cm^2. No such restriction is placed on portable cellular telephones, which typically expose operators to radiation levels of 10-20 mW/cm^2.

The researchers recommended that the manufacturers of diathermy devices should indicate the maximum safe distances and directions that must be maintained by therapists. Of course, the subject undergoing treatment

[33] *J. F. Lehmann, et al., "A Comparison of Patterns of Stray Radiation from Therapeutic Microwave Applicators Measured Near Tissue-Substitute Models and Human Subjects," Radio Science 14, no. 6S (November-December 1979):271-83.*

is not maintaining any distance. However, if there must be defined some safe distance to be maintained from devices emitting 5.0 mW/cm² then certainly we might expect some safe distance to be kept from devices emitting higher levels of radiofrequency radiation - portable cellular telephones. This should be especially true when the spacings are being considered with reference to the human brain.

9

Research reports clearly show that in order to feel any sensation from cellular telephone radiofrequency radiation the energy level would be high enough to cause tissue destruction - prior to noticing any heating sensation.

That's because the radiofrequency energy from a portable cellular telephone is absorbed deep into tissue such as the human brain. Since the human brain has little, if any, sensory capability, damage or trauma occurring internally will not be felt until the effects, such as heating, are so severe that they work their way outward. If tissue damage occurs within a localized region of the brain it may be completely unnoticed - for the present, that is. These researchers also confirmed that the threshold for irreversible skin damage is about 45°C.[34] which is also the temperature at which pain is felt. So, by the time a person, exposed to radiofrequency radiation, feels pain at the skin that skin is irreversibly damaged, as is the deeper tissue beneath the skin. They also pointed out

[34] *J. F. Lehmann, et al., "Comparison of Relative Heating Patterns Produced in Tissues by Exposure to Microwave Energy at Frequencies of 2,450 and 900 Megacycles," Archives of Physical Medicine and Rehabilitation, February 1962, pp. 69-76.*

that excessive internal heating of muscle tissue is not felt as an burning sensation; it is noticed as a dull aching sensation. Similarly, internal heating of brain tissue would not be sensed as a burning sensation. Likely, there would be no sensation at all.

Interest in the ability to "sense" the presence of high levels of radiofrequency radiation motivated researchers to determine threshold levels for detecting heat sensations due to radiation exposure.[35] These researchers found that at 2,450 MHz a minimum exposure to a power density of 26.7 mW/cm^2 was necessary to induce a sensation of heating in a test subject. This is very close to the previously reported exposure levels for threshold of warmth sensation at 2,450 MHz. Recall that 2,450 MHz radiation has been found to deposit energy mostly near the surface, whereas 845 MHz energy is deposited into deeper tissue layers. The researchers concluded that "the same set of superficial thermoreceptors was being stimulated" as were stimulated by infrared energy heating. Not surprisingly, infra-red energy exposure was detected at a much lower power density of only 1.7 mW/cm2. Research shows that as the frequency is reduced the power density required for a sensation of warmth increases. Infrared energy has a much higher frequency than 2,450 MHz.

At 845 MHz the threshold for sensation shifts to a much higher level. That is, one must be exposed to dramatically higher levels of radiofrequency radiation at 845 MHz before the warmth sensation is noticed. With 845 MHz radiation exposure the threshold power density for

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[35] *D. R. Justesen, "A Comparative Study of Human Sensory Thresholds: 2450-MHz Microwaves vs Far-Infrared Radiation," Bioelectromagnetics 3, no. 1 (1982):117-25.*

sensation of warmth occurs at about 90 mW/cm^2. Such a high power density level is enough to cause severe destruction to deep tissue.

There is a broad range of potentially lethal exposures below that level that would remain undetected by thermal sensations. Considering our previous discussion of the lack of sensory detectors in the brain, we can expect that no warning of brain tissue destruction would be provided to a cellular telephone user until the damage was so extensive that the scalp, which absorbs very little energy, sensed heating.

10

In an unusual report a product manufacturer provides information related to the "unexplored" area of heating of simulated tissue. It's curious that the researchers should describe the technical area as unexplored, particularly in view of the full body of prior research, only some of which has been described here, and in view of the many products the manufacturers have in the marketplace. Their measurements indicate that radiation exposures could exceed a power density of 10 mW/cm^2. There is value in the research as they observed and documented an energy absorption "hot spot" associated with high electric fields at the tip of their antenna.

A health hazard is present in the event that the user places the tip of the antenna in the immediate vicinity of the eye.[36]

[36] *Q. Balzano, et al., "Heating of Biological Tissue in the Induction Field of VHF Portable Radio Transmitters," IEEE Transactions on Vehicular Technology VT-27, no. 2 (May 1978):51-6.*